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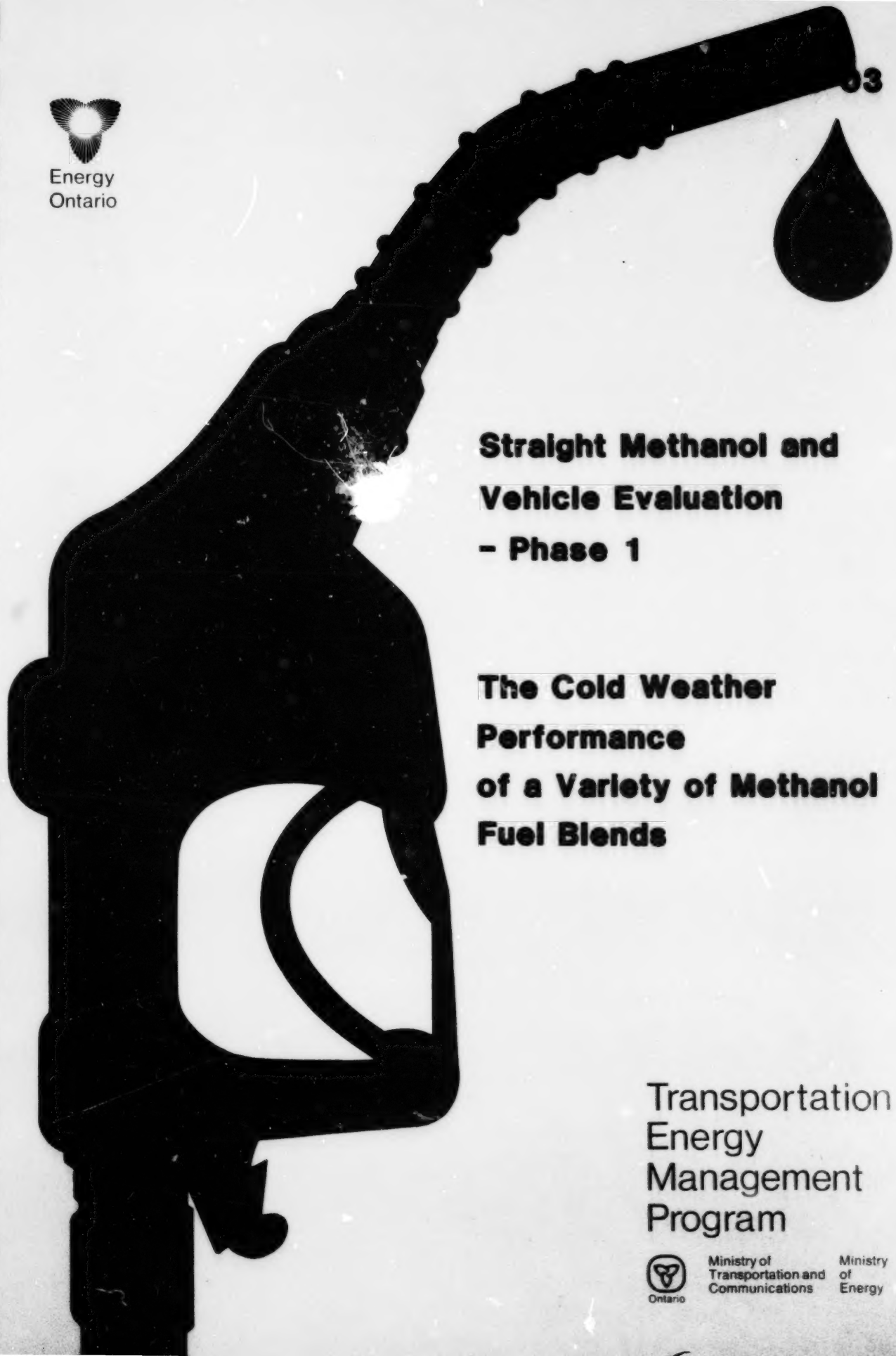

Straight Methanol and Vehicle Evaluation - Phase 1

The Cold Weather Performance of a Variety of Methanol Fuel Blends

Transportation
Energy
Management
Program

Ontario
Ministry of Transportation and Communications
Ministry of Energy

Technical Report Documentation Page

MTC Report Number AF-84-03	ISBN Number:	Other Document Number:	Date: Aprii 1984

Title: Straight Methanol and Vehicle Evaluation -- Phase 1
The Cold Weather Performance of a Variety of Methanol Fuel Blends

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Published by:
The Transportation Technology and Energy Branch, MTC
Ontario Ministry of Energy

Client Group:
Transportation Energy Management Program

Participating Agencies:
Shell Canada Limited

Abstract: This report presents the results and evaluations of adding volatile blending agents to methanol.
A variety of volatile blending agents were added to methanol and evaluated in two 193 model Ford Escorts which were factory-equipped for operation on near-neat methanol fuel. The addition of these agents help alleviate the poor cold weather startability and driveability associated with the use of methanol in spark-ignition engines.

Key Words: straight methanol fuel, cold weather driveability, startability

Comments:

Distribution: by request

Copyright Status: Crown Copyright

AF-84-03

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The Cold Weather Performance of a Variety of Methanol Fuel Blends

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Published by:
The Transportation Energy Management Program

Transportation Technology and Energy Branch
Ontario Ministry of Transportation and Communications
Hon. James W. Snow, Minister
H.F. Gilbert, Deputy Ministry

Ontario Ministry of Energy
Hon. Philip Andrewes, Minister
D.M. Allan, Deputy Minister

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The Editor, Technical Publications
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

April 1984

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FOREWORD

The work described in the report was part of a project jointly funded by Shell Canada, Ford of Canada and by the Ontario Provincial Government. It is a component of the Transportation Energy Management Program (TEMP) administered by the Ministry of Transportation and Communications and the Ministry of Energy in Ontario.

SUMMARY

A variety of volatile blending agents have been added to methanol and evaluated in two 1983 model Ford Escorts which were factory-equipped for operation on near-neat methanol fuel.

The addition of volatile blending agents to methanol helps to alleviate the poor cold weather startability and driveability associated with the use of this fuel in spark-ignition engines.

The tests undertaken included cold startability, cold driveability, fuel economy and regulated exhaust emissions. Water tolerance and weathering characteristics of some of the blends were also investigated. Operational problems associated with the fuel are also discussed.

The results show that the minimum start temperature, with no aids, on the best blends was circa -20°C. This compares with a figure of -29°C obtained with a gasoline-powered Ford Escort. Cold driveability was not as good as similar gasoline-powered automobiles. However, regulated exhaust emissions were comparable.

The combined fuel economy figures obtained at 25°C were approximately 57% of the Transport Canada combined figure for similar gasoline-powered Ford Escorts. The methanol fuel blend contains approximately 55% of the energy of the gasoline.

A variety of operational problems were evident due to the fuel. This included limited vehicle range, approximately 250 to 280 km, filter plugging due to fuel system corrosion, and some spark plug pre-ignition damage.

This program is continuing in 1984 via a fleet durability trial involving eight 1983 Ford Escorts at Shell Canada Limited and a similar number at Ford Motor Company of Canada Ltd.

1/ INTRODUCTION

Methanol is seen as a promising alternative liquid fuel for transportation as it can be used in conventional spark-ignition engines with limited modifications. Methanol is presently produced from natural gas but can be produced from other sources such as coal or possibly biomass, sewage or solid waste.

Methanol has a lower energy density than gasoline. However, due to its higher octane rating and higher latent heat of evaporation than gasoline, a higher compression ratio can be used. This results in both a higher thermal efficiency and greater power output compared to gasoline.

The high latent heat of evaporation and low vapour pressure associated with methanol causes significant cold weather startability and driveability problems. These problems are of major concern if methanol is to be used as a transportation fuel in Canada.

In order to alleviate these problems, blends of methanol with other volatile agents have been proposed. Possible agents include light hydrocarbons such as butanes, pentanes and hexanes, and various oxygenates such as dimethyl ether.

This report details the evaluation of a variety of fuel blends under cold weather operating conditions in two Ford Escorts. The two vehicles were developed to operate on a blend of 90% by volume methanol and 10% by volume winter grade non-leaded gasoline.

2/ TEST METHODS

2.1/ Test Cars

The test vehicles were two 1983 Ford Escorts developed by Ford Motor Company to operate on a blend of 90% by volume methanol and 10% by volume winter grade non-leaded gasoline. Ford developed this methanol version of an Escort to operate in the state of California.

Modifications to the cars are given in Table 1. The cars were calibrated to 1983 U.S. Emission Standards (0.25 g HC/km, 4.3 g CO/km, 0.62 g NO_x/km), which includes a waiver provision on CO emissions.

The cars were equipped with 1.6L-L4-2V engines and 3 speed automatic transmissions. Their emission systems include a three-way catalyst, exhaust gas recirculation and an air pump. Various vehicle specifications are given in Table 2. However it should be noted that the catalyst was only being used oxidatively.

Initially the cars were operated for 1000 km on the suggested 90/10 mix of methanol and gasoline. The oil used was the factory fill, an SAE 30 grade, specifically developed for methanol-fuelled vehicles.

Subsequent to this a 10W20 oil, again formulated for methanol-fuelled vehicles and an auxiliary fuel system, were installed in the vehicles.

The auxiliary fuel system consisted of a three-way valve in front of the car's fuel pump, and a stainless steel pressure container with quick disconnect fittings. The o-rings associated with the container were either Viton or Neoprene. These o-rings were replaced as soon as any evidence of leakage was apparent. The fuel container was located on the test cell floor to one side of the front of the car during testing.

2.2/ Test Fuels

A total of 27 test fuels were blended for use in this program. The base components included four oxygenates:

- methanol,
- dimethyl ether,
- methyl tertiary butyl ether, and
- methylal.

The hydrocarbon base components used were normal-butane, iso-pentane, super non-leaded gasoline and lighting naphtha. The super non-leaded gasoline was a winter grade product from Shell Canada's Oakville Refinery. Lighting naphtha consists of C-5, C-6 and C-7 saturated hydrocarbons. Various inspection properties of the base components are given in Table 4.

There was one single-component blend used, namely 100% by volume methanol. Sixteen blends consisted of methanol and one other component. The remaining nine blends contained methanol and two other components. Table 5 lists the blends and their compositions.

The test fuel matrix originally contained ten blends. The list was expanded based on the results obtained with the original ten and input from other interested parties.

Blending was done on a volume basis for the liquid components. All blending was performed at subzero temperatures. The two semi-gaseous components, normal-butane and dimethyl ether were blended by mass. These components were chilled to -20°C and added by bubbling a gas-liquid mixture into the bottom of the blend container, until the desired mass was obtained.

All the blended fuels were stored at temperatures between -20°C and 0°C in sealed containers, until required.

2.3/ Vehicle Tests

Tests on the vehicles included the following:

1) Cold Startability. The two cars were tested in a cold-soak facility capable of operation down to -30°C. The facility force cools the cars via the use of refrigerator coils and fans. A total of 27 fuels were

evaluated. Not all fuels were tested on both cars due to time and equipment constraints. Cranking speed was maintained reasonably constant via the use of a battery charger and blanket. No additional aids (i.e., block or sump heaters) were used. The cars were tested for startability when the ambient, coolant in the head and engine oil temperature were within ±1°C of each other. The cars, if they started, were operated for a maximum of five minutes. This allowed a more rapid testing schedule to be used. However, a minimum of two hours forced cooling was used between tests.

The tests were performed at approximately 5°C intervals over the range of +10°C to -30°C. The starting sequence is given in Table 3. A chart recording of battery voltage versus time was used to check cranking speed and time to start. An example of the chart is given in Figure 1.

When the fuel blend was changed, usually every day or two, the cars were warmed-up and driven until the oil sump temperature exceeded 90°C.

2/ Cold Driveability. A total of six fuels were evaluated for cold weather driveability at ±5 and -10°C, on both cars. Due to the warm conditions during the winter of 1982/83 the normal procedure by Shell Canada Limited at the Oakville Research Centre (ORC) was adjusted.

The two cars were parked in the cold-soak facility at the test temperature (either +5 or -10°C) for a minimum of 16 hours. The cars were then pushed outside and the normal procedure followed, if the ambient temperature was within 10°C of the test temperature. Only the first ten cycles of the procedure were analysed again due to the differences between the test and ambient temperatures. Startability, normally included in the evaluation, was discounted as it was evaluated separately.

The normal driveability procedure used by Shell Canada is described in Appendix A. This procedure is more severe than that used by the Coordinating Research Council (CRC), a U.S. based industry group, in their cold weather testing.

3/ Water Tolerance. A total of eight fuel blends were tested for water tolerance. The tests were performed at +20 and -20°C. The method used was to add distilled water to a small sample until separation occurred. Separation is the most important criterion as generally the hydrocarbon component separates from the bulk of the fuel blend which could cause operational problems in cold weather.

4/ Weathering. Eight fuel blends were tested for mass loss over time. Two types of containers were used -- namely flasks and beakers. Both containers were tested at two temperatures, +20 and -20°C. No analysis of the type of components lost was performed. The mass loss versus time should indicate the relative ease with which the more volatile blending component was lost. Two containers were used to see if the area open to atmosphere versus the surface area of the fuel had any noticeable effect on weathering rate.

5/ Exhaust Emissions. Regulated exhaust emissions -- namely carbon monoxide (CO), unburnt hydrocarbons (HC) and oxides of nitrogen (NO_x) -- were measured over the city and highway cycles at +25 and -10°C. The tests were performed per the U.S. Federal Test Procedure (FTP) in the ORC Chassis Dynamometer Facility. Both cars were tested on two fuels at each temperature.

6/ Fuel Economy. The fuel economy over both the city and highway cycles was measured at +25 and -10°C in the ORC Chassis Dynamometer Facility. Both cars were tested on the two fuels selected for exhaust emission testing. Additionally steady state fuel economy was measured at 60 and 100 km/h. Typical road-use figures were also obtained on both cars, with the 90% by volume methanol, 10% by volume super non-leaded gasoline blend.

7/ Other Test Criteria. Any operational difficulties with the two vehicles were monitored. Finally, the accelerative ability of the two cars was determined.

3/ RESULTS AND DISCUSSION

3.1/ Cold Startability

Initially some tests were run on car 330, the Blue Escort, to define a starting procedure. The chosen procedure is indicated in Table 3. Table 7 shows some results with car 330 using alternate starting procedures.

The 1983 Ford Escort Owner Guide indicates that a gasoline-powered Escort should have the accelerator pedal depressed to the floor twice before each starting attempt between 0 and -18°C. Below -18°C the accelerator should be depressed eight times before each attempt.

The time to first fire figures' given in Table 7 indicate that in the range from -10 to -18°C four or less initial depressions of the accelerator are insufficient with methanol fuel. Six initial accelerator pedal depressions were then chosen as the starting procedure over the test temperature range of 0 to -30°C.

On each subsequent starting attempt the gasoline-powered Ford Escort Owner Guide indicates an identical number of pedal pumps should be used. Due to the possibility of flooding with methanol fuel, a lower number, two, was used for subsequent starting attempts as indicated in Table 3.

The latest version of the methanol-powered Escort starting instructions shows that three pedal depressions should be used between 0 and -18°C, and five below -18°C. As the starting procedure shown in Table 3 was used consistently throughout the program, the differences between it and the present Ford recommendation should have no effect on the relative performance of the fuels.

Both a battery charger and blanket type battery heater were used to ensure that the engine cranking speed remained reasonably constant over the temperature range of interest. Typically the cranking speed varied between 150 and 200 rpm.

Any fuel which did not give a start after 30 s of cranking below -15°C on either car were eliminated immediately. Table 8 indicates these fuels and test results. The elimination of these fuels left a total of 14 candidates, six containing methanol and one component and eight containing methanol and two components.

Due to time and equipment constraints the final six fuel blends, numbers 21 through 26, were tested after an initial selection of fuels for driveability, fuel economy and exhaust emissions from the prior 21 fuels. Only one fuel out of this group was eliminated due to the 30 s to start at -15°C criterion.

Table 9 lists the 14 candidates, test results and the estimated time to start with 30 s of cranking for each car/fuel combination. The estimates were based on the assumption that the time to start varied as a power of the absolute value of the test temperature. The relationship was also assumed to be asymptotic to both minimum temperature and to zero time to start. An example is given in Figure 2.

Table 10 summarizes the results with the final 14 blends. The average of the temperatures to start, with 30 s of cranking for the two cars and their ranks are given. The average result for the five fuels tested on one car only were estimated based on the difference between the two cars with the other nine fuels. In general, car 331 would start at a temperature 1.25°C below that of car 330, with 30 s of cranking.

The top four fuels, which started at temperatures between -21°5 and -18.5°C were, in order:

- 9% by volume iso-pentane,
- 15% by volume super non-leaded gasoline,
- 10% by volume super non-leaded gasoline with 5.0% by mass added dimethyl ether, and
- 10% by volume normal butane.

The results given in Table 10 were not indicated by either the distillation range or Reid Vapour Pressure (RVP) of the individual blends (as given in Table 6). This is in contrast with gasoline where RVP and distillation range are good indicators of cold temperature startability.

The property which may most easily be related to startability is the blends' latent heat of evaporation. Pure methanol has a latent heat of evaporation of 1.17 MJ/kg at 25°C and 1 atmosphere compared to gasoline which typically is 0.35 MJ/kg. Attempts were made to develop a reliable method to experimentally determine the latent heat. This method is still under development at this time.

In general, the time to start results were as expected, namely: as the concentration of the solute increased, the minimum start temperature decreased. The blends containing dimethyl ether (DME) were the exception to this trend. The blend containing 9.0% by mass DME in methanol proved very troublesome giving poor results on one car and a series of no starts with the other car (see Table 9). This was probably due to the excessive vapour pressure of the blend causing almost immediate flooding. The blend of 10% by volume super non-leaded gasoline in methanol with 7.5% by mass added DME also reacted in a similar but less severe manner.

The above indicates that blends containing higher concentrations than 7.5% by mass DME alone or 5.0% by mass DME with one other solute should be avoided with this particular vehicle design.

Appendix C gives some data generated at the Oakville Research Centre (ORC) with gasoline-powered Ford Escorts. This data indicates that the car started, unaided, on gasoline at -29°C with a similar cranking time. The approximate 9°C difference between the best methanol blends and gasoline may be impossible to reduce further by fuel blend modifications. Some other method of increasing the amount of fuel vaporization may have to be devised.

3.2/ Cold Driveability

As mentioned in the above section the six fuels evaluated for cold weather driveability were selected from fuel blends 0 through 20, based on cold start results.

Table 11 details the results obtained. At -10°C the 7.5% by mass dimethyl ether blend failed to start on one test due to flooding. This shows, again, that higher concentrations of this solute seem to give

operational problems. The results for this blend at +5°C were accidentally discarded after the end of testing.

The results at either +5 or -10°C again do not relate very well to the inspection properties of the blends. Generally, with gasolines of similar vapour pressures, the cold weather driveability performance can be related to some combination of the T10, T50 and T90 points, where these are, respectively, the temperature, in °C, where 10%, 50% and 90% of a sample of gasoline has evaporated in the ASTM D-86 distillation test. Alternately, the performance can be related to the E100 point, namely the percentage of fuel evaporated at 100°C again in the ASTM D-86 test.

These blends, all containing a large amount of methanol, have extremely flat distillation curves. Generally, between the 10% evaporated and 90% evaporated points, the curve is on the boiling point of methanol, namely 64°C. The different blends give slightly different shapes above and below these values, but nothing of any significance.

The flat distillation curve negates the possibility of gasoline-type volatility controls being useful with near-neat methanol fuels. The property which could most likely describe the cold weather driveability results is the latent heat of evaporation of the total fuel blend. In summary, conventional gasoline-type inspection properties do not appear to be relevant to near-neat methanol fuel cold weather performance.

The ORC driveability procedure quantitatively evaluates hesitations, stumbles, backfire and stalls. Three of these four characteristics usually occur during transient operation and should be a function of the propensity with which the fuel vaporizes in the intake manifold. The latent heat of evaporation should help to define the relative propensity for vaporization of the fuel blends.

The results in Table 11 also show that, on the average, driveability demerits increase by 13%/1°C drop in ambient temperature. Gasoline-powered cars typically show a slightly lower increase in demerit level as temperature drops.

The best three fuels at +5°C were, in order;
- 10% lighting naphtha,
- 15% super non-leaded gasoline, and
- 10% butane.

The best three at -10°C were, in order;
- 15% super non-leaded gasoline,
- 2.0% butane and 8.0% lighting naphtha, and
- 10% butane.

The demerit level with these fuels can be compared to some of the gasoline based data given in Appendix C. The average level at +5°C with the five methanol blends tested was 39. This compares to 28 using a typical winter gasoline. Similarly, at -10°C, the six blends tested gave an average of 57 demerits versus 42 for a typical winter gasoline. The above figures show that the methanol conversion gives approximately 1.38 times as many demerits as gasoline. The levels of driveability demerits are still acceptable compared to the average levels found with gasoline-powered cars tested at ORC from 1977 to 1982.

3.3/ Water Tolerance

Table 12 gives water tolerance test results with eight blends as well as pure methanol and pure super non-leaded gasoline. The tests were performed at both -20 and +20°C. The relative rankings of the eight fuel blends did not change significantly with temperature. The water tolerance at -20°C was, on the average, 70% of its +20°C value, by mass.

The rank of the fuel blends was basically a function of the level of hydrocarbon in the blend. The use of dimethyl ether in a given blend increased the water tolerance by effectively decreasing the mass percent of hydrocarbon present. All of the blends had a significantly higher tolerance of water than pure gasoline.

In general, to minimize water tolerance problems, the portion of hydrocarbons present should be minimized. Additionally, as the level of aromatics in a hydrocarbon increases its ability to absorb water increases, so high aromatic content hydrocarbons are also beneficial. The super non-leaded gasoline used in this study contained 35% by volume aromatics,

1% by volume olefins and 64% by volume saturates. Lighting naphtha is generally 95% by volume saturates and 5% by volume aromatics.

3.4/ Weathering

Weathering tests were performed on the same eight fuels as the water tolerance tests and at the same two temperatures. Two vessels were used, small cylindrical beakers and small conical flasks. The results, namely; time to lose 50 and 100% of the additive mass, are given in Table 13. The flask results at -20°C are not given as the samples never lost more than 50% of the additive mass during the 300-min test period.

In general, the time to lose 50 and 100% of the additive mass at either +20 and -20°C ordered the same. However, comparing the +20 and -20°C results shows some large changes in order.

The lighter added components, apart from 7.5% by mass dimethyl ether which was the worst in all but one case, showed much higher relative weathering losses at the lower temperature, as might be expected. The specific blends which changed order were 10% by volume butane and the 10% super non-leaded blends spiked with dimethyl ether.

The heavier added components, the 10% by volume lighting naphtha and the 2% butane, 8% lighting naphtha, blend showed better relative weathering losses as the test temperature was decreased. This, again, is as would be expected based on the vapour pressure of the added components and their concentrations in the blend.

The best blends at both temperatures were the two 10% super non-leaded blends spiked with dimethyl ether, the 15% super non-leaded blend and the 10% lighting naphtha blend.

3.5/ Exhaust Emissions

Two fuels were tested for exhaust emissions at +25 and -10°C. The two fuels were chosen from fuel blends 0 through 20 due to the initial time and equipment constraints on the project. The results are shown in Table 14. Full results are shown in Appendix B. The chosen fuel blends were 15% super non-leaded and the 2% butane, 8% lighting naphtha blend.

Both cars meet 1983 Canadian Emission Standards at +25°C. The cars easily pass the 1983 CO and NO_x U.S. Standards but failed the unburnt HC level by a small amount.

At -10°C the emissions of unburnt HC and CO increased dramatically compared to +25°C. The levels of increase are similar to that experienced with gasoline-powered vehicles in prior tests at ORC. The emissions of NO_x increased by approximately 10% over the +25 to -10°C range. This is also similar to gasoline-powered vehicles (Reference 9).

The two cars performed differently. Car 330 gave higher unburnt HC, lower CO and higher NO_x emissions than car 331. This is due to slight differences in calibration -- namely car 331 had a leaner setup than car 330.

Aldehyde emissions were not measured in this program as they are not presently regulated and suitable equipment was not available in time.

3.6/ Fuel Consumption

The fuel consumption, measured gravimetrically, was determined at 60 and 100 km/h and over the EPA cycle at +25 and -10°C. The same two fuels as used for exhaust emissions were tested. Table 15 gives the results. Full results are given in Appendix B.

The fuel consumption at +25°C was better with the 15% super non-leaded (SNL) blend. This is partially due to the difference in net heating values. Based on the data in Table 4, the net heating value of the 15% SNL blend is 18.2 MJ/L. The net heating value of the 2% butane, 8% lighting naphtha blend is 17.2 MJ/L. The latter is approximately 6% lower than the former. However, the higher level of methanol in the latter blend will give a higher latent heat of vaporization which should give greater efficiency with a fully warmed-up engine under road load conditions.

There is a benefit to fuel economy from the latent heat, as opposed to the analysis in Appendix D, as the test is performed at road loads well below maximum output. Appendix D assumes wide open throttle conditions, which will show a power benefit due to the differences in latent heats.

The relative differences between the two blends varied from 2.4 to 9.0% at 25°C as given in Table 15, with the 15% SNL blend having lower fuel consumption. This shows that at higher ambients fuel consumption is dependent on net heat content.

At -10°C the differences were much lower, the range being between 0.1 and 3.0% relative difference. These lower differences are probably due to better vaporization characteristics with the 2% butane, 8% lighting naphtha blend at lower temperatures. Even the relative difference in fuel consumption under steady state conditions (60 and 100 km/h) are lower at -10°C than +25°C. This indicates that the fuel vaporization may still be very important even under fully warmed-up conditions.

Car 330 gave lower fuel consumption, under the majority of conditions, compared to car 331. This is per the emission results.

Appendix C gives some fuel consumption figures for a similar gasoline-powered Ford Escort. The combined figure is 7.5 L/100 km. The two fuel blends, when tested at +25°C, gave an average of 13.1 L/100 km. The former figure is 57% of the methanol figure.

Appendix D details some calculations regarding the fuel consumptions of methanol and gasoline Ford Escorts. The conclusion is that these particular methanol cars should have a fuel consumption of 1.72 times that of the gasoline-powered equivalent (or 0.58 times the fuel economy). Factors included were compression ratio, power output, lean misfire limit, net heating content differences and the effect of increased fuel capacity to preserve vehicle range.

Additionally, it should be mentioned that the Transport Canada figures are for an Escort calibrated to Canadian Emission Standards, whereas the methanol Escorts are really calibrated to U.S. Emission Standards. This may give some added benefit to the fuel consumption of the Canadian calibrated gasoline Escort.

The fuel consumption of both fuel blends increased as the temperature was decreased. The 15% SNL blend fuel consumption increased by 21.6% or by 0.62% per 1°C drop in temperature. The 2% butane, 8% lighting naphtha blend had increases of 15.5% or 0.44% per °C drop. This compares favourably with prior work done at ORC on a variety of gasoline-powered cars (Reference 9).

The over-the-road fuel consumption figures obtained were 14.7 L/100 km for car 330 over 1400 km and 13.3 L/100 km for car 331 over 2900 km. The approximate range per tank was between 250 and 280 km. The fuel used was the 10% by volume super non-leaded blend. The ambient conditions involved temperatures around 20°C. Earlier in the year, with temperatures below 0°C, car 331 records 18.2 L/100 km over 425 km. This figure reflects the service, specifically short trip driving under winter conditions. Further fuel consumption figures will be generated in Phase II of this program.

3.7/ Other Test Criteria

Car 330 was tested for accelerative capability yielding the following:

0	to	50 km/h:	5.6 s
0	to	100 km/h:	16.0 s
50	to	100 km/h:	11.8 s

These figures compare favourably to the results given in Appendix C for a manual transmission equipped, gasoline-powered Ford Escort.

A variety of other problems were encountered with these two cars. Both cars had plugged fuel filters at some point during testing. This was due to the tendency of methanol to pick up contaminants from and corrode the various fuel containers used.

Both cars also knocked on the 10% by volume super non-leaded blend at approximately 70 to 80 km/h under maximum throttle without downshift conditions. This was probably due to a slight miscalibration of the distributor spark advance.

Car 330 also encountered pre-ignition problems when operated at 120 km/h under almost full throttle conditions. The number 3 cylinder spark plug side electrode melted back onto the centre electrode and shorted out. This prevented further possible pre-ignition damage but the car ended up running on three cylinders. This, again, is probably due to excessive distributor spark advance.

The oil used in this program was a specially formulated 10W20 suitable for use with methanol fuel. This oil would form an emulsion with the fuel washed down the cylinder walls after as few as two cold starts. The emulsion, if left, would separate into two or three distinct layers. The top layer was a light brown foam, the middle clear and dark brown similar to the oil when new. The bottom layer looked like solids in suspension, and was usually greyish-brown in colour. The oil could be restored by ensuring the sump temperature exceeded approximately 70°C.

Questions regarding oil will be addressed in Phase II of the program.

4/ CONCLUSIONS

1/ These methanol-fuelled cars can be started down to circa -20°C with no aids, and 30 seconds of cranking with four of the 27 fuel blends tested. The blends were 9% iso-pentane, 15% super non-leaded gasoline, 10% butane and a blend of 10% super non-leaded gasoline spiked with 5% by mass dimethyl ether.

2/ Driveability with these cars is poorer than with equivalent gasoline cars. There is no obvious inspection property that controls driveability performance. The driveability performance is still acceptable compared to the average of gasoline-powered cars tested at ORC between 1977 and 1982.

3/ Water tolerance of the blends is better than gasoline. The water tolerance is a function of the hydrocarbon content of the blend.

4/ All the blends weathered to some extent. The blends which yielded the least weathering losses were the two 10% super non-leaded gasoline blends spiked with dimethyl ether.

5/ The cars gave acceptable levels of regulated exhaust emissions compared to the 1983 U.S. Standard. As temperature dropped, emissions increased at a similar rate to gasoline-powered cars. Aldehyde emissions were not measured.

6/ The fuel consumption of the two vehicles was as expected from a simple energy analysis. The methanol blend gave 1.75 times the fuel consumption (or 0.58 times the fuel economy) of gasoline at +25°C. Fuel consumption increased as temperature dropped at a similar level as has been found with gasoline-powered cars. The fuel consumption of the 2% butane, 8% lighting naphtha blend decreased less with temperature than the 15% super non-leaded blend.

7/ The methanol-fuelled Escort has more power than its gasoline equivalent. Pre-ignition may be a problem with methanol fuel. Material compatibility and/or fuel dispensing system cleanliness may also be a problem area with methanol fuel.

5/ RECOMMENDATIONS

The cold start data indicates that the four blends, as listed above in the summary, are suitable choices. The driveability results indicate that there is not a large variation in vehicle response to differing fuel blends.

The exhaust emission results were acceptable with the blends tested. The fuel consumption figures were as expected based on prior work with gasoline and the net heating value of the test fuel.

Water tolerance results showed that the level of hydrocarbon present should be minimized. Weathering results indicated that blends containing two components, a hydrocarbon and an ether performed better than blends of either of these components alone.

Additionally, Reference 5 indicates three other important concerns regarding blend suitability.

1/ Flame Luminosity must be increased. This is most easily attained by the addition of aromatic hydrocarbons.
2/ Blend Denaturing and Identification. This, again, is most easily accomplished by adding hydrocarbons, particularly aromatics.
3/ Flammability limits of the vapour phase above a pool of liquid methanol fuel. The use of 10% gasoline in methanol alleviates this problem to a large extent.

The blend chosen from the 27 blends tested should reflect both the above concerns and the program conclusions. This indicates that a hydrocarbon component should be included, be aromatic in nature and at a minimum amount, up 10% by volume or less. The most suitable blend is then 10% by volume super non-leaded in methanol, spiked with 5.0% dimethyl ether.

The exhaust emissions, fuel economy and cold weather driveability of this blend will be in the range of those tested. The blend allowed starts to -19.5°C and had both good water tolerance and weathering characteristics.

Further work in this area should be performed to optimize this blend of hydrocarbon, ether and methanol, again reflecting the tests performed in this program and the concerns mentioned above.

Finally, it appears that even with an optimum blend some other, possibly mechanical, modifications must be used to obtain similar cold weather performance as that obtained with late model gasoline-powered cars.

REFERENCES

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[5] Anderson, J.E., and Nichols, R.J., "Fuel Methanol Additives: Issues and Concerns," Ford Motor Company, 1983.

[6] Bernstein, L.S., and Panzer, J., "Priming Agents for Methanol as an Automotive Fuel," 5th International Alcohol Fuel Technology Symposium, New Zealand, 1982.

[7] Gardner, D.P., and Bardon, M.F., "Cold Starting Tests on a Methanol-Fuelled Spark-Ignition Engine," SAE Paper 831175.

[8] Goodger, E.M., Hydrocarbon Fuels, John Wiley and Sons, 1975, New York, New York.

[9] Grinberg, L., "Study of Relative Fuel Efficiencies under Canadian Climatic Conditions of Automobiles with Advanced Engine Designs," ORC Report 79/006.

Table 1/ Modifications to the Base Ford Escort for the Methanol Fuel

Fuel System

- Stainless Steel Fuel Tank
- Nickel-Plated Brass Float and Sending Unit (in tank)
- Nylon-Coated Fuel Tank Straps
- Stainless Steel Fuel Lines
- Nickel-Plated Fuel Pump
- Nickel-Plated, Recalibrated, Carburettor
- New Carburettor Spacer with Incorporated Electrical Heating Unit

Engine (1.6L H.O. Version)

- 11.8:1 Compression Ratio Pistons
- 1 Top Piston Ring, Barrel Faced and Hard Chromed
- 1984 Head Gasket, with a Stainless Steel Fire Ring
- Base 1.6L Camshaft
- Distributor with Modified Advance Curves
- AWSF 12C Spark Plugs (two heat ranges colder than the plugs used in the gasoline Escort)

Table 2/ Test Vehicle Specifications

Model	1983 Ford Escort
Body Style	4 Door Hatchback
Engine Type	Overhead Cam, in line 4 cylinder
Bore x Stroke, mm	80 x 79
Capacity, L	1.6
Compression Ratio	11.8:1
Combustion Chamber	Compound Valve Hemispherical (CVH)
Transmission Type	3 speed Automatic
Emission Calibration	1983 U.S. with a CO waiver

Table 3/ Cold Startability Testing Sequence

1/ Ignition switch on.
2/ Wait for warning buzzer to stop.
3/ Depress accelerator six times.
4/ Crank for 10 s (foot off accelerator).
5/ Stop for 10 s.
6/ Depress accelerator twice.
7/ Repeat steps 4, 5 and 6 as necessary to a maximum for 5 further times.
8/ If no start, remove plugs, dry, and reinstall.
9/ If start, run for 5 min then shut off.
10/ Adjust ambient temperature to reflect test results.
11/ Allow at least 2 h before next test.
12/ Test when ambient, oil in sump and coolant in head are within ±1°C.

Table 4/ Base Component Inspection Properties

BASE COMPONENT	NET HEATING VALUE MJ/kg	LATENT HEAT OF EVAPORATION MJ/kg	DENSITY kg/L	MOLECULAR WEIGHT	% CARBON BY MASS	RON	MON	SENSITIVITY (= R-M)	IBP °C	DISTILLATION RANGE 10% 50% 90% % evap @ °C			EP °C	REID VAPOUR PRESSURE kPa	CHEMICAL FORMULA
Methanol	19.9	1.17	0.792	32.04	37.5	111	90	21	64	-	-	-	-	32	CH_3OH
N-butane	45.3	0.39	0.579	58.12	82.8	94	90	4	-0.5	-	-	-	-	356	C_4H_{10}
Iso-pentane (2-Methylbutane)	44.9	0.34	0.620	72.15	83.2	92	90	2	28	-	-	-	-	141	C_5H_{12}
Lighting naphtha	44.5*	0.31*	0.692	99.00*	84.3	67*	65*	2*	62	72	81	96	108	30	C_7H_{15}*
Super non-leaded gasoline	43.5	0.35	0.739	111.00*	87.4	96.5	86.6	9.9	25	37	105	164	198	99	C_8H_{15}*
Dimethyl ether	28.9	0.49	0.661	46.07	52.1	?	?	?	-25	-	-	-	-	~850	CH_3OCH_3
Methylal (dimethoxymethane)	?	0.35	0.863	76.09	47.3	?	?	?	42	-	-	-	-	>44	$CH_2(OCH_3)_2$
Methyl tert butyl ether	35.1	0.32	0.737	88.14	68.2	117	102	15	55	-	-	-	-	45	$C_4H_9OCH_3$

*Estimated from composition.

These inspection properties have been obtained from various sources.

Table 5/ Blend Composition

BLEND NO.	BLEND NAME	COMPONENTS																	
		MeOH		N-BUTANE		ISO-PENTANE		LIGHTING NAPTHA		SUPER NON-LEADED GASOLINE		DIMETHYL ETHER		METHYLAL		METHYL TERT BUTYL ETHER	
		% vol	% mass	% vol	% mass	% vol	% mass	% vol	% mass	% vol	% mass	% vol	% mass	% vol	% mass	% vol	% mass
0	100 MeOH	100.0	100.0														
1	5 Butane	95.0	96.3	5.0	3.7												
2	10 Butane	90.0	92.6	10.0	7.4												
3	6 Pentane	94.0	95.2			6.0	4.8										
4	9 Pentane	91.0	92.8			9.0	7.2										
5	6 LN	94.0	94.7					6.0	5.3								
6	10 LN	90.0	91.2					10.0	8.8								
7	6 SNL	94.0	94.4							6.0	5.6						
8	10 SNL	90.0	90.6							10.0	9.4						
9	15 SNL	85.0	86.0							15.0	14.0						
10	5 DME	-	95.0									-	5.0				
11	7 DME	-	92.5									-	7.5				
12	9 DME	-	91.0									-	9.0				
13	10 Methylal	90.0	89.2											10.0	10.8		
14	15 Methylal	85.0	83.9											15.0	16.1		
15	10 MTBE	90.0	90.6													10.0	9.4
16	15 MTBE	85.0	85.9													15.0	14.1
17	1.2 B/4.8 SNL	94.0	94.6	1.2	0.9					4.8	4.5						
18	2 B/8 SNL	90.0	91.0	2.0	1.5					8.0	7.5						
19	2 B/8 LN	90.0	91.4	2.0	1.5			8.0	7.1								
20	5 B/5 LN	90.0	91.5	5.0	3.7			5.0	4.8								
21	6 SNL/5 DME	-	89.9							-	5.3	-	4.8				
22	6 SNL/7.5 DME	-	87.8							-	5.2	-	7.0				
23	10 SNL/5 DME	-	86.3							-	8.9	-	4.8				
24	10 SNL/7.5 DME	-	84.3							-	8.7	-	7.0				
25	6 LN/7.5 DME	-	88.1					-	4.9				7.0				
26	10 LN/7.5 DME	-	84.8					-	8.2				7.0				

Table 6/ Inspection Properties of Select Blends

BLEND NO.	BLEND NAME	DENSITY kg/L	% CARBON BY MASS	DISTILLATION RANGE IBP °C	10% %	50% evap @ °C	90% °C	EP °C	% RECOVERY	REID VAPOUR PRESSURE kPa	WATER CONTENT mg/kg	(R+M)/2 ESTIMATE
0	100 MeOH	0.792	37.5	64	64	64	64	64	98.7	31.7	660	100.5
2	10 Butane	0.780	40.9	34	63	64	64	80	95.5	>100.0	-	100
4	9 Pentane	0.782	40.8	33	60	64	64	71	97.6		-	100
6	10 LN	0.792	41.6	59	63	64	64	70	98.8	69.5	-	97
8	10 SNL	0.791	43.1							51.3	-	100
9	15 SNL	0.788	44.5	44	61	64	65	176	98.6	56.7	-	99
10	5 DME	0.792	38.2	46	63	64	64	66	99.0	76.0	-	<98[e]
11	7.5 DME	0.790	38.6	38	59	64	64	76	93.7	89.3	-	<98[e]
19	2 B/8 KN	0.783	41.5	46	60	64	64	76	98.2		-	98
23	10 SNL/5 DME	0.781[c]	42.7[c]								-	<98[e]
24	10 SNL/7.5 DME	0.778[c]	42.9[c]								-	<98[e]

[c] -- Calculated from base component values.

[e] -- Estimate based on a low value for DME octane quality (i.e., circa 70 (R+M)/2).

Table 7/ The Effect of Starting Procedure on Startability

PUMPS ON INITIAL ATTEMPT	PUMPS ON SUBSEQUENT ATTEMPTS	TEST TEMPERATURE, °C	TIME TO FIRST FIRE, s	TIME TO START, s	RUN NUMBER
2	1	-10	0.1	24.0	2
3	1	-15	10.5	>55.1	3
4	2	-16	6.2	>47.3	1
4	2	-18	0.4	>95.8	16
6	1	-13	0.5	47.6	13
6	2	-11	0.5	>62.7	66
6	3	-16	0.8	64.6	15
8	1	-18	0.5	>59.6	12
8	2	-15	0.6	44.6	14

All tests were performed on tank fuel (90% vol MeOH/10% vol SNL-w).

All tests were performed on car 330, Blue.

Table 8/ Initial Blends Eliminated

BLEND NO.	BLEND NAME	ESTIMATED TEMPERATURE TO START WITH 30 s OF CRANKING °C		INDIVIDUAL TEST RESULTS							
				1		2		3		4	
		330, BLUE	331, RED	TEMP. °C	TIME TO START s	TEMP. °C	TIME TO START s	TEMP. °C	TIME TO START s	TEMP. °C	TIME TO START s
0	100 MeOH	-1	NA	0	26.8	-5	NS	-15	NS	-	-
1	5 Butane	-5	NA	-8	37.6	-8	50.8	-12	43.6	-18	87.4
3	6 IPT	-15	NA	-12	9.2	-15	36.2	-20	NS	-	-
5	6 LN	-9	NA	-2	6.0	-5	1.4	-10	56.0	-16	76.6
7	6 SNL	-8	NA	-5	10.2	-10	71.2	-15	NS	-	-
8	10 SNL	-11	NA	0	2.0	-6	8.6	-10	22.2	-12	75.2
10	5 DME	NA	-11	-2	4.2	-10	32.4	-12	41.0	-19	NS
13	10 Methylal	NA	-8	-4	4.4	-9	85.4	-14	NS	-19	NS
14	15 Methylal	-14	NA	-6	7.2	-9	8.0	-15	NS	-20	NS
15	10 MTBE	NA	-6	-3	3.2	-7	NS	-19	NS	-	-
16	15 MTBE	-11	NA	-2	3.6	-8	17.4	-19	NS	-	-
17	1.2 B/4.8 SNL	-7	NA	+4	1.2	-4	15.0	-12	69.6	-15	NS
25	6 LN/7.5 DME	-13	NA	-1	10.0	-8	7.1	-9	6.7	-15	82.3

NS - No start after 60 s of cranking, if the engine was about to start at 60 s a time was determined. All these blends were eliminated as their time to start at -15°C was greater than 30 s.

Table 9/ Startability Tests with Final Fourteen Blends

BLEND NO.	BLEND NAME	CAR NO.	ESTIMATED TEMPERATURE TO START WITH 30 s OF CRANKING °C	INDIVIDUAL TEST RESULTS 1 TEMP. °C	1 TIME TO START s	2 TEMP. °C	2 TIME TO START s	3 TEMP. °C	3 TIME TO START s	4 TEMP. °C	4 TIME TO START s	5 TEMP. °C	5 TIME TO START s
2	10 Butane	330	-17	-11	22.8	-16	21.2	-17	47.4	-21	54.2	-27	NS
		331	-20	-6	6.6	-15	5.2	-26	NS	-	-	-	-
4	9 Pentane	330	-23	-12	7.2	-16	8.0	-21	16.2	-25	NS	-	-
		331	-20	-9	3.4	-16	9.4	-21	50.6	-	-	-	-
6	10 LN	330	-18	-5	2.4	-13	5.2	-18	81.8	-19	68.4	-24	NS
		331	-14	-5	1.3	-10	7.9	-16	71.6	-25	NS	-	-
9	15 SNL	330	-19	-12	12.2	-13	7.6	-19	31.0	-25	NS	-	-
		331	-21	-7	3.8	-11	8.2	-17	13.2	-22	54.6	-	-
11	7.5 DME	330	-18	-7	16.0	-8	2.8	-12	19.8	-14	7.0	-19	29.6
		331	-18	-7	4.8	-16	11.8	-17	20.6	-	-	-	-
12	9 DME	330	-20	-3	4.6	-11	13.8	-20	25.8	-26	NS	-	-
		331	NS	-11	NS	-19	NS	-20	NS	-	-	-	-
18	2 B/8 SNL	330	-17	+3	0.9	-4	4.1	-14	21.0	-20	43.3	-22	NS
		331	NA										
19	2 B/8 LN	330	NA										
		331	-18	-5	4.4	-13	10.2	-17	23.0	-19	47.4	-24	NS
20	5 B/5 LN	330	-17	-1	1.4	-6	4.4	-13	12.4	-17	37.0	-23	NS
		331	NA										
21	6 SNL/5 DME	330	NA										
		331	-17	-14	21.0	-15	26.8	-21	45.3	-	-	-	-
22	6 SNL/7.5 DME	330	-16	-3	6.2	-4	1.7	-6	11.9	-15	25.3	-19	NS
		331	-20	-2	1.6	-6	9.3	-10	7.0	-21	31.6	-	-
23	10 SNL/5 DME	330	-18	0	1.2	-6	6.2	-9	7.2	-14	54.8	-19	32.7
		331	-21	0	1.7	-7	1.4	-12	11.1	-18	9.7	-22	3.6
24	10 SNL/7.5 DME	330	-13	-2	1.6	-10	21.9	-16	NS	-17	42.2	-21	17.8
		331	-18	-3	1.1	-10	38.8	-13	17.0	-17	7.7	-23	NS
26	10 LN/7.5 DME	330	NA										
		331	-16	-1	4.7	-11	5.0	-16	29.5	-16	NS	-	-

NS - No Start

Table 10/ Summary of Startability Tests with Final Fourteen Blends

BLEND NO.	BLEND NAME	ESTIMATED TEMPERATURE TO START WITH 30 s OF CRANKING, °C		DIFFERENCE BETWEEN 331 RESULT AND 330 RESULTS	AVERAGE OF 331 RESULT AND 330 RESULT	RANK OF AVERAGE RESULT
		330 BLUE	331 RED	°C	°C	
2	10 Butane	-17	-20	-3	-18.5	4
4	9 Pentane	-23	-20	+3	-21.5	1
6	10 LN	-18	-14	+4	-16	11
9	15 SNL	-19	-21	-2	-20	2
11	7.5 DME	-18	-18	0	-18	5
12	9 DME	-20	NS	?	?	?
18	2 B/8 SNL	-17	NA	-	-17.6*	7
19	2 B/8 LN	NA	-18	-	-17.4*	9
20	5 B/5 LN	-17	NA	-	-17.6*	7
21	6 SNL/5 DME	NA	-17	-	-16.4*	10
22	6 SNL/7.5 DME	-16	-20	-4	-18	5
23	10 SNL/5 DME	-18	-21	-3	-19.5	3
24	10 SNL/7.5 DME	-13	-18	-5	-15.5	12
26	10 LN/7.5 DME	NA	-16	-	-15.4[1]	13
Average Difference between 331 and 330 results, C°				-1.25		

* Average result is based on correcting the single car data point by one-half the average difference between the two cars' results

NA -- Not Available

Table 11/ Summary of Driveability Results Obtained

TEST TEMPERATURE °C	BLEND NO.	BLEND NAME	DRIVEABILITY DEMERIT LEVELS CAR 330 RUN 1	CAR 330 RUN 2	CAR 330 AVERAGE	CAR 331 RUN 1	CAR 331 RUN 2	CAR 331 AVERAGE	OVERALL AVERAGE	RANK
+5	2	10 Butane	30	31	31	48	51	50	41	3
	4	9 Pentane	42	46	44	69	62	66	55	5
	6	10 LN	11	8	10	12	22	17	14	1
	9	15 SNL	23	18	21	36	64	50	36	2
	11	7.5 DME			NA				NA	NA
	18	2 B/8 LN	49	54	52	39	58	46	49	4
-10	2	10 Butane	24	34	29	67	96	82	55	3
	4	9 Pentane	31	40	36	95	75	85	61	4
	6	10 LN	47	57	52	83	95	89	71	5
	9	15 SNL	41	32	37	53	59	56	47	1
	11	7.5 DME	70	64	67	56	NS	56	62	4
	18	2 B/8 LN	38	31	35	56	54	55	45	1

NA - Not Available

NS - No Start

Demerit Level based on cycles one to ten only, not including starting characteristics.

2 Raters were used. Rater 2 = 0.88 x Rater 1 from prior testing.

Table 12/ Water Tolerance Test Results

BLEND NO.	BLEND NAME	TEST TEMP. °C	AMOUNT OF WATER REQUIRED TO CAUSE BLEND SEPARATION				TEST TEMP. °C	AMOUNT OF WATER REQUIRED TO CAUSE BLEND SEPARATION				AVERAGE OF BOTH RANKINGS
			mL	% vol	% mass	Rank		mL	%vol	%mass	Rank	
2	10 Butane	+20	17	18	21	2	-20	11	12	15	2	2
4	9 Pentane	+20	15	16	19	3	-20	11	12	15	2	3
6	10 LN	+20	6	7	9	6	-20	3	4	5	8	7
9	15 SNL	+20	5	6	7	8	-20	4	5	6	6	7
11	7.5 DME	+20	-	-	-	1	-20	-	-	-	1	1
19	2 B/8 LN	+20	6	7	9	6	-20	4	5	6	6	6
23	10 SNL/5 DME	+20	8	9	11	5	-20	6	7	9	4	5
24	10 SNL/7.5 DME	+20	9	10	13	4	-20	6	7	9	4	4
	100 MeOH		-	-	-			-	-	-		-
	100 SNL		<1	<1	<2			<1	<1	<2		

The initial sample of the blend was 80 mL.

Table 13/ Weathering Test Results

BLEND NO.	BLEND NAME		TIME TO LOSE 50% OF ADDITIVE MASS						TIME TO LOSE 100% OF ADDITIVE MASS						
		MeOH % mass	Mass Lost % mass	Flask @+20°C min	Beaker @+20°C min	Rank @+20°C	Beaker @-20°C min	Rank @-20°C	Mass Lost % mass	Flask @+20°C min	Beaker @+20°C min	Rank @+20°C	Beaker @+20°C min	Rank @-20°C	Ave. of all 4 Ranking
2	10 Butane	92.6	3.7	340	30	7	50	4	7.4	1050	80	6	120	4	5
4	9 Pentane	92.8	3.6	360	20	6	30	7	7.2	690	60	7	80	8	7
6	10 LN	91.2	4.4	860	40	1	50	4	8.8	2400	80	1	90	6	3
9	15 SNL	86.0	7.0	690	80	2	70	3	14.0	1250	160	3	160	3	3
11	7.5 DME	92.5	3.8	210	10	8	20	8	7.5	520	50	8	90	6	8
19	8 LN/2 B	91.4	4.3	520	20	3	60	6	8.6	1250	50	4	120	4	4
23	10 SNL/5 DME	86.3	6.8	520	20	3	110	2	13.6	2500	70	1	>300	1	2
24	10 SNL/7.5 DME	84.3	7.9	420	10	5	130	1	15.7	1280	50	4	>300	1	3

Table 14/ Exhaust Emission Results

BLEND NO.	BLEND NAME	CAR NO.	TEST TEMPERATURE °C	EMISSIONS OVER THE CITY CYCLE, g/km HC	CO	NO_x
9	15 SNL	330	+25	0.33	2.56	0.52
			-10	2.24	18.17	0.50
		331	+25	0.23	2.88	0.28
			-10	1.95	19.73	0.44
		AVERAGE	+25	0.28	2.72	0.40
			-10	2.10	18.95	0.47
19	2 B/8 LN	330	+25	0.45	2.37	0.54
			-10	1.70	14.93	0.52
		331	+25	0.22	2.41	0.29
			-10	1.16	14.93	0.37
		AVERAGE	+25	0.34	2.39	0.43
			-10	1.43	14.93	0.45
	1983 Canadian Standards for Gasoline-Powered Cars		+25	1.2	15.5	1.9
	1983 U.S. Standards for Gasoline-Powered Cars (Including a CO Waiver Provision)		+25	0.25	4.3	0.6

Table 15/ Fuel Consumption Results

BLEND NO.	BLEND NAME	CAR NO.	TEST TEMPERATURE °C	FUEL ECONOMY, L/100 km WEIGHTED CVS	HIGHWAY CYCLE	COMBINED CYCLE	STEADY STATE 60 km/h	STEADY STATE 100 km/h	
9	15 SNL	330	+25	14.23	10.23	12.43	8.30	11.40	
			-10	17.83	11.30	14.89	9.72	12.26	
		331	+25	14.56	10.59	12.77	8.25	11.71	
			-10	18.84	11.96	15.74	9.34	12.76	
		AVERAGE	+25	14.40	10.41	12.60	8.28	11.56	ROW 1
			-10	18.34	11.63	15.32	9.53	12.51	ROW 2
19	2 B/8 LN	330	+25	14.89	10.59	12.96	8.43	11.63	
			-10	18.26	11.11	15.04	9.18	12.27	
		331	+25	16.50	11.09	14.07	8.74	12.05	
			-10	19.48	12.16	16.18	10.46	12.98	
		AVERAGE	+25	15.70	10.84	13.52	8.59	11.84	ROW 3
			-10	18.87	11.64	15.61	9.82	12.63	ROW 4
	RELATIVE DIFFERENCES $\frac{\text{ROW 1 - ROW 3}}{\text{ROW 1}} \times 100$, %			-9.0	-4.1	-7.3	-3.7	-2.4	
	$\frac{\text{ROW 2 - ROW 4}}{\text{ROW 2}} \times 100$, %			-2.9	-0.1	-1.9	-3.0	-1.0	

Fuel Consumption results were obtained gravimetrically.

L/100 km = 282.48/MPIG

L/100 km = 235.22/MPUSG

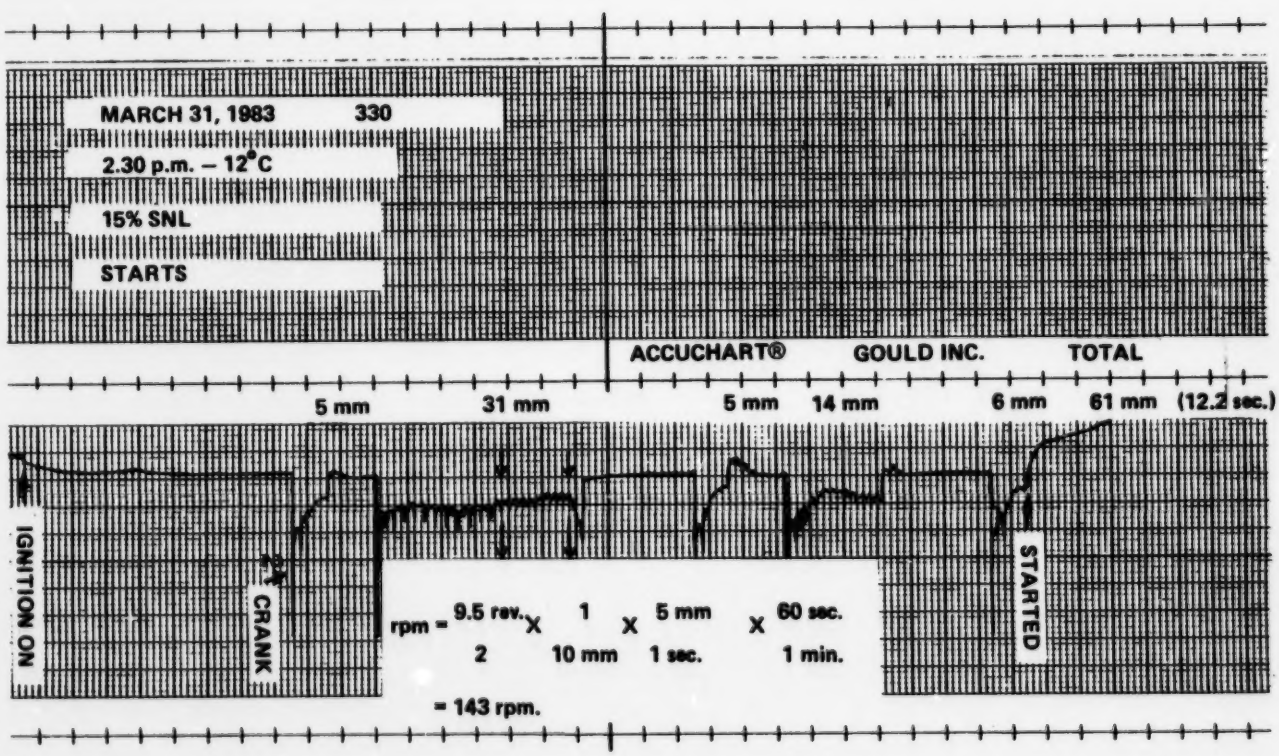


Figure 1/ Battery Voltage Versus Time to Start Trace

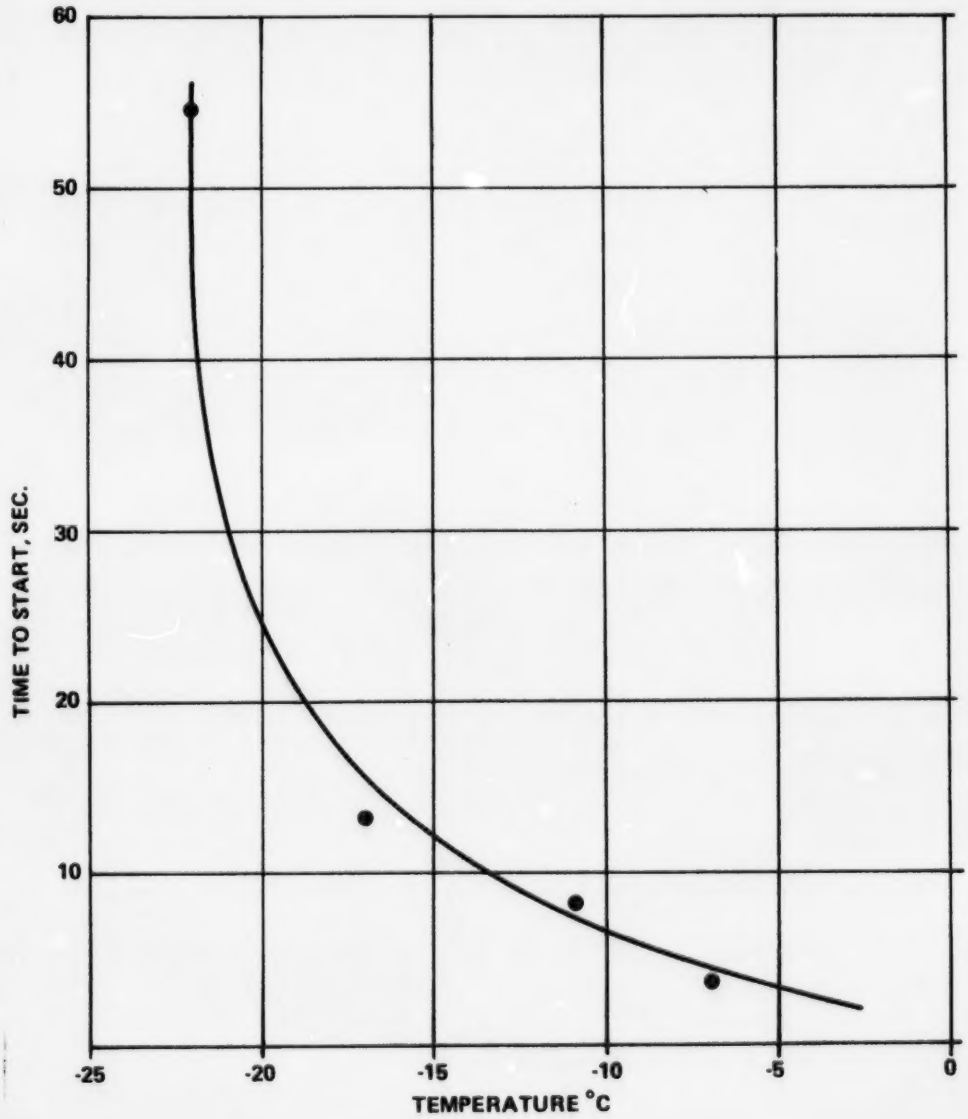
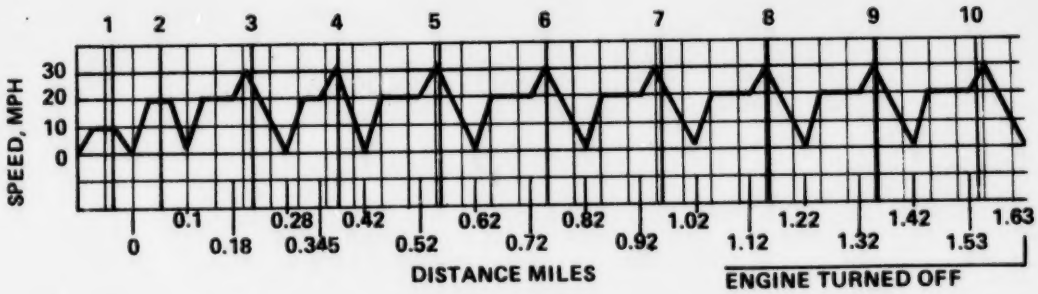


Figure 2/ Temperature Versus Time to Start Curve.
Car 331 on 15% SNL Blend

Appendix A-1/ ORC Driveability Procedure



1/ The engine is started according to the manufacturer's recommended starting procedure. It is allowed to idle for 10 s in neutral at fast idle, for 10 s in neutral at reduced rpm and for 10 s in a gear.

2/ The initial driveaway (step 1) consists of a part throttle acceleration to 10 mph, a short cruise at that speed, deceleration to a full stop and a five s idle period.

3/ The second driveaway mode (step 2) consists of a full throttle acceleration to 20 mph, a short cruise at that speed, deceleration to a full stop and a 5 s idle period.

4/ Steps 3-10 are practically identical. They consist of a part throttle acceleration to 20 mph, a short cruise at that speed, a full throttle acceleration to 30 mph, a short cruise at that speed, deceleration to a full stop and a 5 s idle period.

Appendix A-2/ Driveability Rating System

	Demerits assigned to driveability malfunctions of various severities					
	TRACE	LIGHT	MODERATE	HEAVY	SEVERE	YES
Hesitation	4	8	12	18	24	
Stumble	4	8	12	18	24	
Backfire	4	6	8	10	12	
Surge	3		6		9	
Stall at Idle						18
Stall, driving						42
Idle Roughness	1		2		3	

1/ All stalls during the initial 30 s, during later five-second idle periods, and during decelerations are considered to be idle stalls.

2/ When totalizing demerits, no more than one backfire is counted for each deceleration If the sum of driving demerits due to hesitations, stumbles, surges, backfires and stalls exceed 84 for one acceleration the demerits in excess of 84 are not counted.

Appendix B/ Fuel Economy and Exhaust Emissions Results

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	330 BLUE
DESCRIPTION OF TEST	=	EMISSIONS; -10°C
DATE OF TEST + OTHER INFO	=	83.05.17; 15% SNL
DYNAMOMETER RUN NUMBER(S)	=	5963-4-5-6
DYNO WINDAGE SETTING	=	1.77
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7881
FUEL-PERCENT CARBON	=	44.51
ODOMETER READING	km =	1604.0
VEHICLE INERTIA WEIGHT	kg =	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST	km =	17.85
ACTUAL HIGHWAY DIST	km =	16.54
AMBIENT BAROMETRIC PRESSURE	=	30.01
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0015
RELATIVE HUMIDITY, PERCENT	=	100.0

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 4.61	HC = 1.79	HC = 1.32
CO = 36.49	CO = 4.27	CO = 11.81
NO_x = 0.74	NO_x = 0.31	NO_x = 0.68
CO_2 = 213.83	CO_2 = 190.27	CO_2 = 166.47

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 2.24	CO = 18.17	NO_x = 0.50	CO_2 = 188.6
HIGHWAY	HC = 0.20	CO = 3.62	NO_x = 0.54	CO_2 = 142.2

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	1399.19	5.76
STAB COLD =	1054.43	6.30
TRANS COLD =	873.11	5.79
HIGHWAY =	1868.80	16.54

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	22.24	24.29	8.44 (1 stall)
STAB COLD =	17.00	16.74	-1.54
TRANS HOT =	14.73	15.08	2.34
WEIGHTED CVS =	17.46	17.83	2.11
UNWEIGHTED =	17.96	18.64	3.63
HIGHWAY =	11.56	11.30	-2.33
COMBINED RATING =	14.80	14.89	0.59

*** STEADY STATES ***

1/100 km at 60 km/h = 9.72
1/100 km at 100 km/h = 12.26

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	331
DESCRIPTION OF TEST	=	EMISSIONS; -10°C
DATE OF TEST + OTHER INFO	=	83.05.19; 15% SNL
DYNAMOMETER RUN NUMBER(S)	=	5973-4-5-6
DYNO WINDAGE SETTING	=	1.87
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7881
FUEL-PERCENT CARBON	=	44.51
ODOMETER READING	km =	1200.0
VEHICLE INERTIA WEIGHT	kg =	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST	km =	17.88
ACTUAL HIGHWAY DIST	km =	16.47
AMBIENT BAROMETRIC PRESSURE	=	29.71
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0016
RELATIVE HUMIDITY, PERCENT	=	100.000

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 2.33	HC = 2.42	HC = 0.75
CO = 38.24	CO = 15.34	CO = 14.16
NO_x = 0.56	NO_x = 0.52	NO_x = 0.21
CO_2 = 212.39	CO_2 = 188.45	CO_2 = 184.79

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 1.85	CO = 19.73	NO_x = 0.44	CO_2 = 192.4
HIGHWAY	HC = 0.19	CO = 0.82	NO_x = 0.28	CO_2 = 157.3

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	1462.89	5.73
STAB COLD =	1099.35	6.34
TRANS COLD =	972.21	5.81
HIGHWAY =	1969.67	16.47

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	21.78	25.53	14.68 (2 stalls)
STAB COLD =	17.14	17.34	1.15
TRANS HOT =	16.30	16.73	2.61
WEIGHTED CVS =	17.87	18.84	5.16
UNWEIGHTED =	18.37	19.77	7.06
HIGHWAY =	12.38	11.96	-3.61
COMBINED RATING =	15.40	15.74	2.16

*** STEADY STATES ***

1/100 km at 60 km/h = 9.34
1/100 km at 100 km/h = 12.76

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	330 BLUE
DESCRIPTION OF TEST	=	EMISSIONS; -10°C
DATE OF TEST + OTHER INFO	=	83.05.18; SLN 28
DYNAMOMETER RUN NUMBER(S)	=	5965-6-7-8
DYNO WINDAGE SETTING	=	1.77
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7883
FUEL-PERCENT CARBON	=	41.47
ODOMETER READING	km =	1695.0
VEHICLE INERTIA WEIGHT	kg =	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST	km =	17.86
ACTUAL HIGHWAY DIST	km =	16.48
AMBIENT BAROMETRIC PRESSURE	=	30.17
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0015
RELATIVE HUMIDITY, PERCENT	=	100.0

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 3.50	HC = 1.19	HC = 1.30
CO = 33.37	CO = 11.26	CO = 8.02
NO_x = 0.86	NO_x = 0.34	NO_x = 0.63
CO_2 = 228.45	CO_2 = 184.14	CO_2 = 167.44

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 1.70	CO = 14.93	NO_x = 0.52	CO_2 = 188.7
HIGHWAY	HC = 0.11	CO = 1.48	NO_x = 0.68	CO_2 = 139.0

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	1501.97	5.76
STAB COLD =	1048.59	6.31
TRANS COLD =	874.79	5.79
HIGHWAY =	1819.74	16.48

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	24.38	26.08	6.49 (1 stall)
STAB COLD =	17.17	16.62	-3.33
TRANS HOT =	15.38	15.11	-1.79
WEIGHTED CVS =	18.17	18.14	-0.13
UNWEIGHTED =	18.93	19.18	1.31
HIGHWAY =	11.83	11.04	-7.12
COMBINED RATING =	15.32	14.95	-2.46

*** STEADY STATES ***

1/100 km at 60 km/h = 9.18
1/100 km at 100 km/h = 12.27

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB		=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)		=	331 RED
DESCRIPTION OF TEST		=	EMISSIONS; -10°C
DATE OF TEST + OTHER INFO		=	83.05.19; 8LN 2B
DYNAMOMETER RUN NUMBER(S)		=	5969-70-1-2
DYNO WINDAGE SETTING		=	1.77
DYNO INERTIA SETTING		=	-0.52
FUEL DENSITY (g/mL)		=	0.7833
FUEL-PERCENT CARBON		=	41.47
ODOMETER READING	km	=	1000.0
VEHICLE INERTIA WEIGHT	kg	=	1077.3
DYNO HP (INDICATED)	AT 80 km/h	=	6.0
ACTUAL URBAN DIST	km	=	17.92
ACTUAL HIGHWAY DIST	km	=	16.49
AMBIENT BAROMETRIC PRESSURE		=	29.86
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR		=	0.0016
RELATIVE HUMIDITY, PERCENT		=	100.0

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 2.98	HC = 0.69	HC = 0.70
CO = 29.21	CO = 11.13	CO = 11.45
NO_x = 0.49	NO_x = 0.37	NO_x = 0.28
CO_2 = 218.90	CO_2 = 210.30	CO_2 = 187.99

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 1.16	CO = 14.94	NO_x = 0.37	CO_2 = 206.0
HIGHWAY	HC = 0.06	CO = 1.18	NO_x = 0.35	CO_2 = 147.4

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	1488.19	5.78
STAB COLD =	1132.26	6.33
TRANS COLD =	1034.72	5.81
HIGHWAY =	2005.23	16.49

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	23.05	25.75	10.48 (2 stalls)
STAB COLD =	19.33	17.89	-8.05
TRANS HOT =	17.50	17.81	1.75
WEIGHTED CVS =	19.60	19.48	-0.61
UNWEIGHTED =	19.94	20.40	2.24
HIGHWAY =	12.56	12.16	-3.27
COMBINED RATING =	16.43	16.18	-1.51

*** STEADY STATES ***

1/100 km at 60 km/h = 10.46
1/100 km at 100 km/h = 12.98

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	330
DESCRIPTION OF TEST	=	EMISSIONS; 25°C
DATE OF TEST + OTHER INFO	=	83.05.16; 15% SNL
DYNAMOMETER RUN NUMBER(S)	=	5959-60-1-2
DYNO WINDAGE SETTING	=	1.77
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7881
FUEL-PERCENT CARBON	=	44.51
ODOMETER READING	km =	1496.0
VEHICLE INERTIA WEIGHT	kg =	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST	km =	17.94
ACTUAL HIGHWAY DIST	km =	16.52
AMBIENT BAROMETRIC PRESSURE	=	29.84
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0029
RELATIVE HUMIDITY, PERCENT	=	15.291

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 0.61	HC = 0.18	HC = 0.39
CO = 6.67	CO = 0.45	CO = 0.48
NO_x = 0.87	NO_x = 0.35	NO_x = 0.60
CO_2 = 192.94	CO_2 = 180.31	CO_2 = 160.60

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 0.33	CO = 2.56	NO_x = 0.52	CO_2 = 177.5
HIGHWAY	HC = 0.04	CO = 0.15	NO_x = 0.58	CO_2 = 136.6

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	920.82	5.79
STAB COLD =	898.74	6.25
TRANS COLD =	760.44	5.80
HIGHWAY =	1690.14	16.52

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	15.98	15.90	-0.49
STAB COLD =	14.13	14.15	0.14
TRANS HOT =	13.02	13.11	0.69
WEIGHTED CVS =	14.21	14.23	0.12
UNWEIGHTED =	14.37	14.38	0.06
HIGHWAY =	10.66	10.23	-4.19
COMBINED RATING =	12.61	12.43	-1.47

*** STEADY STATES ***

1/100 km at 60 km/h = 8.30
1/100 km at 100 km/h = 11.40

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	331 TML 280
DESCRIPTION OF TEST	=	EMISSIONS; 25°C
DATE OF TEST + OTHER INFO	=	83.05.16; 15% SNL
DYNAMOMETER RUN NUMBER(S)	=	5955-6-7-8
DYNO WINDAGE SETTING	=	1.77
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7881
FUEL-PERCENT CARBON	=	44.51
ODOMETER READING km	=	******
VEHICLE INERTIA WEIGHT kg	=	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST km	=	17.93
ACTUAL HIGHWAY DIST km	=	16.51
AMBIENT BAROMETRIC PRESSURE	=	29.84
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0029
RELATIVE HUMIDITY, PERCENT	=	15.291

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 0.35	HC = 0.16	HC = 0.27
CO = 5.84	CO = 0.45	CO = 5.29
NO_x = 0.37	NO_x = 0.21	NO_x = 0.33
CO_2 = 196.36	CO_2 = 178.63	CO_2 = 165.00

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 0.23	CO = 2.88	NO_x = 0.28	CO_2 = 178.6
HIGHWAY	HC = 0.04	CO = 0.15	NO_x = 0.35	CO_2 = 137.8

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	900.52	5.78
STAB COLD =	930.47	6.34
TRANS COLD =	788.35	5.81
HIGHWAY =	1748.76	16.51

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	16.08	15.58	-3.23
STAB COLD =	14.00	14.68	4.63
TRANS HOT =	13.55	13.57	0.11
WEIGHTED CVS =	14.31	14.56	1.74
UNWEIGHTED =	14.53	14.61	0.54
HIGHWAY =	10.75	10.59	-1.49
COMBINED RATING =	12.71	12.77	0.53

*** STEADY STATES ***

1/100 km at 60 km/h = 8.25
1/100 km at 100 km/h = 11.71

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB	=	83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)	=	330 BLUE
DESCRIPTION OF TEST	=	EMISSIONS 25°C
DATE OF TEST + OTHER INFO	=	83.05.21 8LN 2B
DYNAMOMETER RUN NUMBER(S)	=	5981-2-3-4
DYNO WINDAGE SETTING	=	1.87
DYNO INERTIA SETTING	=	-0.52
FUEL DENSITY (g/mL)	=	0.7833
FUEL-PERCENT CARBON	=	41.47
ODOMETER READING km	=	****
VEHICLE INERTIA WEIGHT kg	=	1077.3
DYNO HP (INDICATED) AT 80 km/h	=	6.0
ACTUAL URBAN DIST km	=	17.94
ACTUAL HIGHWAY DIST km	=	16.50
AMBIENT BAROMETRIC PRESSURE	=	29.88
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR	=	0.0036
RELATIVE HUMIDITY, PERCENT	=	19.476

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 0.99	HC = 0.17	HC = 0.57
CO = 6.00	CO = 0.59	CO = 3.01
NO_x = 0.99	NO_x = 0.34	NO_x = 0.57
CO_2 = 194.44	CO_2 = 175.25	CO_2 = 161.54

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 0.45	CO = 2.37	NO_x = 0.54	CO_2 = 175.5
HIGHWAY	HC = 0.03	CO = 0.11	NO_x = 0.52	CO_2 = 134.3

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	1032.04	5.79
STAB COLD =	921.36	6.35
TRANS COLD =	778.63	5.80
HIGHWAY =	1746.84	16.50

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	17.40	17.82	2.39
STAB COLD =	14.85	14.51	2.36
TRANS HOT =	14.13	13.42	-5.23
WEIGHTED CVS =	15.18	14.89	-1.92
UNWEIGHTED =	15.44	15.23	-1.40
HIGHWAY =	11.31	10.59	-6.83
COMBINED RATING =	13.44	12.96	-3.73

*** STEADY STATES ***

1/100 km at 60 km/h = 8.43
1/100 km at 100 km/h = 11.63

****** 1975 CVS & HWFET EMISSION TEST RESULTS ******

CAR YEAR, MAKE, MODEL, DISPL, CARB		= 83 FORD ESCORT MEOH
CAR NO. OR LIC. NO. (CATALYST?)		= 331 RED
DESCRIPTION OF TEST		= EMISSIONS; 25°C
DATE OF TEST + OTHER INFO		= 83.05.21; SLN 2B
DYNAMOMETER RUN NUMBER(S)		= 5977-8-9-80
DYNO WINDAGE SETTING		= 1.87
DYNO INERTIA SETTING		= -0.52
FUEL DENSITY (g/mL)		= 0.7833
FUEL-PERCENT CARBON		= 41.47
ODOMETER READING	km	= 1665.0
VEHICLE INERTIA WEIGHT	kg	= 1077.3
DYNO HP (INDICATED)	AT 80 km/h	= 6.0
ACTUAL URBAN DIST	km	= 17.96
ACTUAL HIGHWAY DIST	km	= 16.50
AMBIENT BAROMETRIC PRESSURE		= 29.85
SPECIFIC HUMIDITY, kg MOISTURE/kg DRY AIR		= 0.0065
RELATIVE HUMIDITY, PERCENT		= 34.126

****** MASS EMISSIONS (g/km) ******

TRANSIENT COLD	STABILIZED COLD	TRANSIENT HOT
HC = 0.60	HC = 0.05	HC = 0.28
CO = 4.94	CO = 0.59	CO = 3.99
NO_x = 0.41	NO_x = 0.22	NO_x = 0.32
CO_2 = 195.83	CO_2 = 198.14	CO_2 = 166.94

****** TEST SUMMARY (WEIGHTED AND CORRECTED g/km) ******

CITY	HC = 0.22	CO = 2.41	NO_x = 0.29	CO_2 = 189.2
HIGHWAY	HC = 0.02	CO = 0.13	NO_x = 0.35	CO_2 = 141.0

****** FUEL CONSUMPTION DATA ******

	FUEL CONSUMED IN mL	ACTUAL DISTANCE TRAVELLED IN km
TRANS COLD =	984.68	5.80
STAB COLD =	1112.73	6.36
TRANS COLD =	825.74	5.80
HIGHWAY =	1830.46	16.50

****** FUEL CONSUMPTION ******

*** CVS C/H ***

	CARBON BALANCE L/100 km	DIRECT MEASURE L/100 km	DIFFERENCE PERCENT
TRANS COLD =	17.27	16.98	-1.72
STAB COLD =	16.74	17.50	4.30
TRANS HOT =	14.63	14.24	-2.78
WEIGHTED CVS =	16.28	16.50	1.37
UNWEIGHTED =	16.23	16.28	0.28
HIGHWAY =	11.87	11.09	-6.98
COMBINED RATING =	14.29	14.07	-1.59

*** STEADY STATES ***

1/100 km at 60 km/h = 8.74
1/100 km at 100 km/h = 12.05

Appendix C/ Gasoline-Powered Ford Escort Data

1/ Startability

Car Type : 1982 Ford Escort with a three-speed automatic
Oil Type : 3 types of 10W30
Typical Cranking Speed: 120 rpm
Typical Time to Start : 35 to 40 s
@ minimum temperature to start of -29°C

2/ Driveability

Results on two 1982 Ford Escorts and one 1983 Ford Escort, using a typical winter grade gasoline averaged to the following:

@+5°C : 28 Demerits
@-10°C: 42 Demerits

These values exclude the start and are only for the first ten cycles as per the test procedure used with the methanol cars.

3/ Fuel Economy

Transport Canada gives figures for the 1983 Ford Escort four-door Hatchback of

Urban 9.4 L/100 km
Highway 6.2 L/100 km
Combined 7.5 L/100 km

4/ Acceleration Test Results
(with calibrated speedometer)

Car: 1982 Ford Escort
with a Four-Speed Manual Transmission

0-50 km/h	5.5
0-100 km/h	15.3
50-100 km/h	10.9

Appendix D/ A Comparison of the Fuel Consumption of Methanol- and Gasoline-Powered Ford Escorts

The major differences in the two vehicles at full power conditions are:

1/ Gasoline compression ratio = 9.0:1
whereas the methanol compression ratio = 11.9:1

Based on the air cycle Otto engine analysis

$N_{th} = 1 - \frac{1}{r^{k-1}}$, where r = compression ratio

k = specific heat of air
= 1.4

gasoline: $N_{th} = 0.585$
methanol: $N_{th} = 0.629$

= circa 8% benefit for methanol

2/ The power output of the methanol-fuelled vehicle is increased. This is due mainly to the higher latent heat of evaporation with the methanol fuel allowing better cylinder filling.

This will cause a small deficit to fuel economy circa 2% (Reference 3).

3/ The methanol-fuelled vehicle can operate at slightly leaner limits at part throttle due to its higher lean misfire limit.

The benefit to fuel economy is estimated to be circa 2% (Reference 3).

4/ The methanol-fuelled vehicle requires more fuel for a given driving range.

The deficit is circa 2% (Reference 3).

5/ The methanol blend has a lower net heating content.

From Table 4 of the text:

Methanol blend, average of two tested for fuel consumption is 17.7 MJ/m^3.

For gasoline a typical value is 32.1 MJ/m^3.

The methanol blend has 55% of the energy content of gasoline, on a volume basis.

Totals: 1) 1.08
2) 0.98
3) 1.02
4) 0.98
5) 0.55

Multiplying together gives 0.58. The methanol vehicle should give 58% of the fuel economy (1.72 times the fuel consumption) of a equivalent gasoline-powered vehicle.